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(54) Apparatus for orienting and guiding the application of tools.

(57) In a method and apparatus for orienting and guiding the application of tools, e.g. a surgical tool during carrying out a surgical procedure on a patient, the patient is secured to a subject support (10). A wand (40) is inserted into a tool guide (60). The wand has a tip portion (44), a portion extending along a pointing axis (46) of the wand, an offset portion (42) which is offset from the pointing axis of the wand, and at least two wand emitters (48, 50), mountd in alignment with the pointing axis of the wand. The two emitters selectively emit signals which are received by receivers (14) mounted to a frame assembly (12). The tool guide includes a bore (76) extending along a guide axis. The bore is configured for selectively receiving a tool and the tip portion of the wand. An entry point and a trajectory are identified by the surgeon with the wand in the guide. More specifically, a trajectory and location of the wand are superimposed on a diagnostic image on a monitor (30). If the surgeon is satisfied with the entry point and trajectory shown on the monitor, a surgical tool is inserted into the bore while the tool guide is held along the designated trajectory and at the designated entry point.

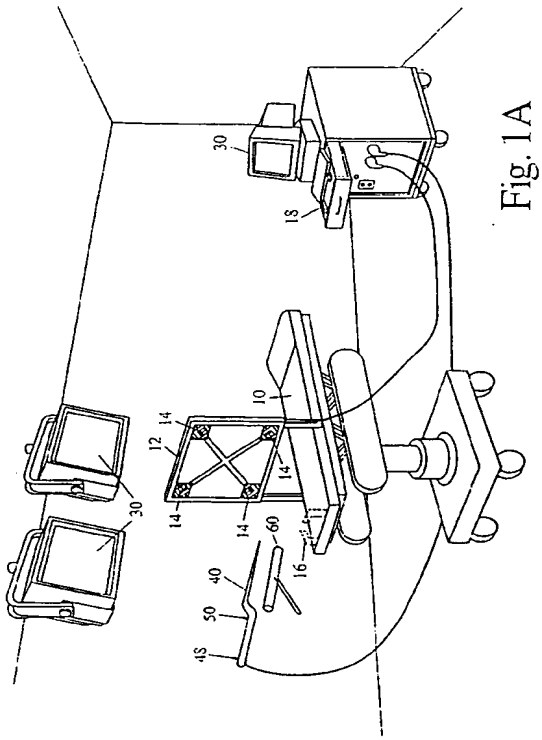

Fig. 1A

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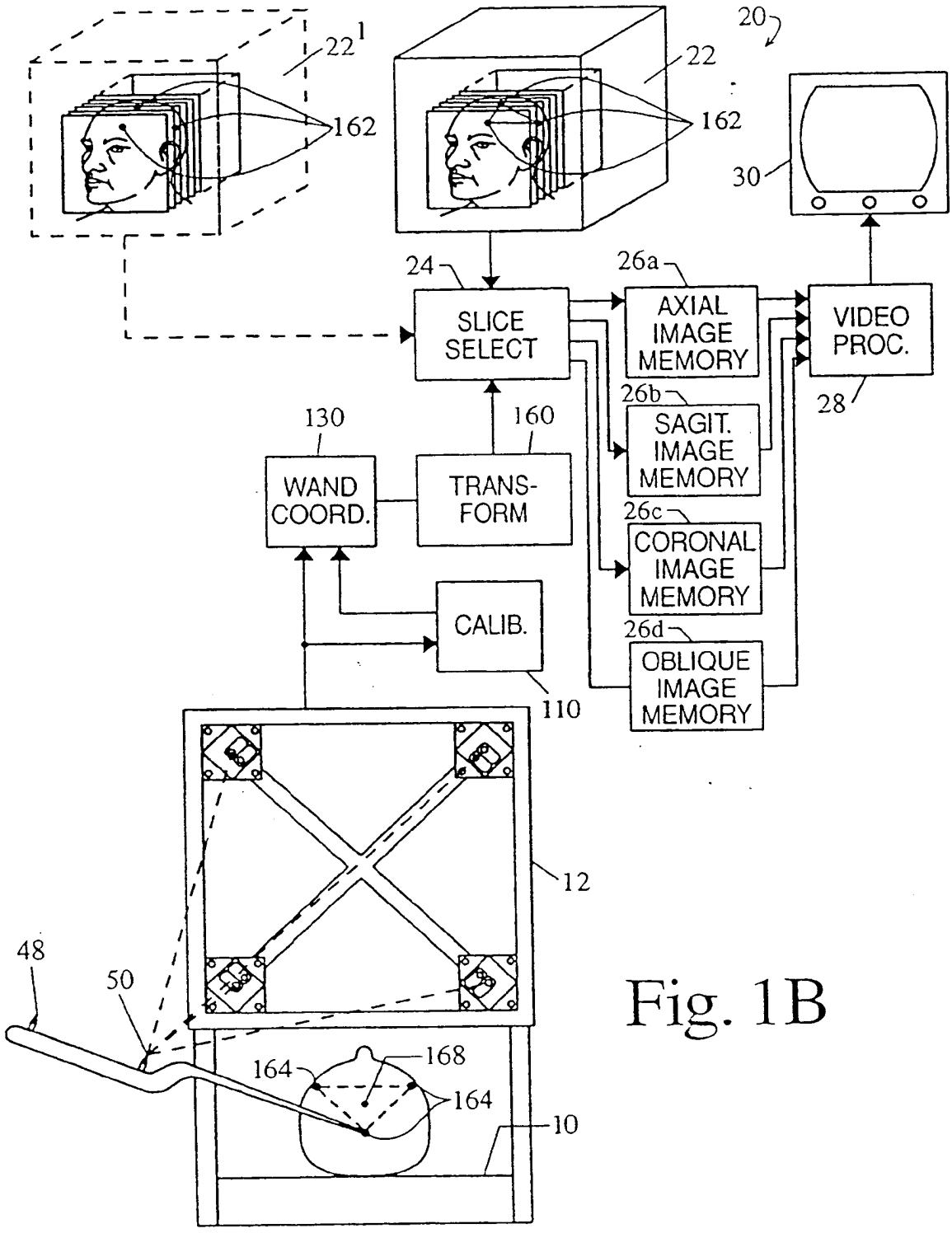

Fig. 1B

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This invention relates to methods and apparatus for orienting and guiding th application of tools. The invention relates especially to such methods and apparatus suitable for use in the medical diagnostic and surgical arts. It finds particular application in conjunction with neurosurgery and will be described with particular reference thereto. However, it is to be appreciated, that the invention will also find application in conjunction with neurobiopsy, CT-table needle body biopsy, breast biopsy, endoscopic procedures, orthopedic surgery, other invasive medical procedures, industrial quality control procedures, and the like.

Three-dimensional diagnostic image data of the brain, spinal cord, and other body portions is produced by CT scanners, magnetic resonance imagers, and other medical diagnostic equipment. These imaging modalities typically provide structural detail with a resolution of a millimeter or better.

Various frameless stereotactic procedures have been developed which take advantage of three-dimensional image data of the patient. These procedures include guided-needle biopsies, shunt placements, craniotomies for lesion or tumor resection, and the like. Another area of frameless stereotaxy procedure which requires extreme accuracy is spinal surgery, including screw fixation, fracture decompression, and spinal tumor removal.

In spinal screw fixation procedures, for example, surgeons or other medical personnel drill and tap a hole in spinal vertebra into which the screw is to be placed. The surgeon relies heavily on his own skill in placing and orienting the bit of the surgical drill prior to forming the hole in the vertebra. Success depends largely upon the surgeon's estimation of anatomical location and orientation in the operative field. This approach has led to suboptimal placement of screws that may injure nerves, blood vessels, or the spinal cord.

The present invention provides methods and apparatus which overcome the above-referenced prob l ms.

In accordance with the invention there is provided an apparatus for orienting and guiding the application of a tool into a subject including: a subject support to which a preselected portion of a subject may be secured and which is selectively positionable in a diagnostic imaging system which includes an image memory for storing reconstructed image representations; a display for displaying selected portions of the image representations stored in the image memory in an image coordinate system; a pointer which is selectively touchable to selected portions of the subject or subject support; an electronic position indicator for providing an electronic indication of points of the subject or subject support portions touched by the pointer in a subject coordinate system; and means for correlating the subject coordinate system with th image coordinate system; the apparatus being characterised by a guide for defining a path extending longitudinally along a guide axis, the guide being configured for selectively receiving a tool along the guide axis; and means connected with the guide for providing electronic signals to the correlating means for coordinating a coordinate system of the guide with the image coordinate system.

The invention also provides a method of orienting a tool and guiding an application of the tool into a subject in which a pointer and guide in combination are maneuvered to a proposed entry point and a trajectory for application of the tool is defined; the method including electronically signaling the trajectory and entry point; correlating a coordinate system of the subject and the signaled entry point and trajectory with a coordinate system of an electronic image representation stored in an image memory; and generating a human-readable display of at least a portion of the image representation with the trajectory and entry point superimposed thereon, the method being characterised by: defining with the guide a tool receiving guide path disposed in alignment with the trajectory; and inserting the tool along the guide path and into the subject along the trajectory through the proposed entry point.

One apparatus and method in accordance with the invention and modifications thereof will now be described, by way of example, with reference to the accompanying drawings in which:-

FIGURE 1A is a perspective view of an operating room in which the apparatus is deployed;

FIGURE 1B is a block diagram of an image data manipulation of the apparatus of FIGURE 1A;

FIGURES 2A, 2B, 2C, 2D, 2E, 2F, and 2G illustrate various embodiments of a wand and guide forming part of the apparatus;

FIGURE 3 is a detailed illustration of a locator assembly of the apparatus;

FIGURE 4 is a diagrammatic illustration of one embodiment of calibration procedure used in the apparatus and method;

FIGURES 5A and 5B are diagrammatic illustrations of the wand and locator assembly relationship;

FIGURES 5C is a flow diagram of a wand location procedure; and

FIGURES 6A, 6B, 6C, and 6D are illustrative of a coordinate transform used in the apparatus and method.

With reference to FIGURE 1A, a subject, such as a human patient, is received on an operating table or other subject support 10 and appropriately positioned within the operating room. A frame 12 is mounted in a fixed relationship to th patient such that it is precisely positioned within the subject or subject support coordinate system. In the illustrated embodiment, the frame 12 is mounted to the patient support 10. Mounting the frame 12 to the patient support permits the pa-

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tient support to be turned, raised, lowered, wheeled to another location, or the like, without altering the patient coordinate system. Alternately, the support may be mounted to a pole or other stationary support, the ceiling of the room, or the like. The frame 12 supports a plurality of receivers 14 such as microphones, radio frequency receivers, light sensitive diodes, other light sensitive receivers, and the like mounted at fixed, known locations thereon. A securing means such as a head clamp 16, securely positions a portion of the subject under consideration. The frame is mounted at a fixed or selectable angle from vertical such that the frame is positionable more toward the patient, yet still focusing on the region of interest of the patient.

With continuing reference to FIGURE 1A and further reference to FIGURE 1B, an operator console 18 houses a computer system 20. Alternately, the computer system can be remotely located and connected with the control console 18 by cabling. The computer system includes a three-dimensional data memory 22. The stored three-dimensional image data preferably contains a video pixel value for each voxel or point in a three-dimensional rectangular grid of points, preferably a 256 x 256 x 256 grid. When each image value represents one millimeter cube, the image data represents about a 25.6 centimeter cube through the patient with one millimeter resolution. Because the data is in a three-dimensional rectangular grid, selectable orthogonal and other oblique planes of the data can readily be withdrawn from the three-dimensional memory using conventional technology. A plane selecting means 24 selects various two-dimensional planes of pixel values from the three-dimensional memory for display.

The plane selecting means selects at least three planes: axial, sagittal, coronal, and oblique planes through a selectable point of the patient. The pixel values which lie on the selected axial, sagittal, coronal, and oblique planes are copied into corresponding image memories 26a, 26b, 26c, and 26d. A video processor means 28 converts the two-dimensional digital image representations from one or more of image memories 26 into appropriate signals for display on a TV monitor 30 or other appropriate display means.

With continuing reference to FIGURE 1A and further reference to FIGURE 2A, a wand 40, formed of suitable resilient material such as metal, has an offset 42 near a tip portion or proximal end 44. The offset 42 is connected to a portion extending along a pointing axis 46 of the wand. In this preferred embodiment, a pair of emitters 48 and 50 are mounted on the offset and disposed along the pointing axis 46 of the wand. The emitters emit a signal that is received by th receivers 14, such as a spark emitter, radio frequency transmitter, infrared LED, or the like. The first emitter 48 is a fixed known distance ℓ_1 from the tip 44 and the second emitter 50 is a fixed known distance ℓ_2 from the first emitter 48. The wand is readily sterilized by conventional techniques. Emitters 48 and 50 emit positioning signals used by a locator system to locate a coordinate and trajectory of the wand. The plane selecting means 24 selects patient image planes based on the coordinate and trajectory located. It is to be appreciated that more than two emitters may be mounted on the offset to provide additional positioning signals to be used by a locator system to locate the coordinate and trajectory of the wand.

The wand 40 is used in conjunction with a guide 60 to designate a coordinate and trajectory at which a surgical tool will be applied to the patient. The guide can be any guide or appliance which positions the wand 40 to establish a surgical trajectory. In the preferred embodiment, the guide 60 is a portable tool which has a handle 62 and a tube member 64 which defines an internal bore 66 to receive and accurately position the wand. The bore 66 of the tool guide has a diameter which allows for the non-simultaneous insertion of either the wand 40 or a surgical tool such as a drill, biopsy needle, and the like. Rather than being hand-held, the guide 60 can be mounted to other structures in the operating room, e.g. framed stereotaxic equipment. In intraoperative use, the wand 40 is inserted in the tool guide bore until the tip 44 aligns with a tool guide distal end 72. A wand stop 70 is positioned on the wand and abuts a proximal end surface 68 of the tool guide when the wand tip aligns with the distal end 72. With the wand tip aligned with the tool guide end, the surgeon may commence probing the patient to seek an optimal coordinate and trajectory in which to insert the appropriate surgical tool. To this end, the surgeon maneuvers the wand and tool guide in combination to a proposed trajectory and actuates the emitters. Signals from the emitters are used in calculating the trajectory 46 and the end point 44 of the wand. The trajectory and end point are displayed on the monitor 30 superimposed on the three-dimensional image or selected image planes. The details of the process for correlating the coordinate system of the patient and the wand with the coordinate system of the image data is described below.

By viewing the display 30, the surgeon can identify the location of the wand tip with respect to anatomic structure, and the trajectory of the bore. If the trajectory is satisfactory, the wand is removed, the surgical tool is inserted, and the procedure is performed. If the trajectory is unsatisfactory, the wand is repositioned and its new trajectory determined and evaluated. This approach improves surgical planning when compared with prior approaches in which surgeons relied solely on their own estimation of the patient's anatomy. Following the identification of the appropriate trajectory and coordinate, the wand 40 is removed from th bore 66 of the guide 60 while the guide is held in position. Holding the guide 60 steady preserves the appropriate trajectory and position coordinates in the axial and sagittal planes determined

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by the wand. Thereafter, the appropriate surgical tool or appliance is inserted within the guide 60. With this approach, the surgical tool is properly positioned in the appropriate trajectory required to perform the surgical procedure.

The wand and tool guide are particularly useful in accurately identifying the optimal entry point, trajectory, and depth of insertion of screws to be placed into the patient's spinal column, as will be more fully described below.

With reference to FIGURES 2B, 2C, and 2D alternative embodiments of the present invention are shown in which the guide is integrated into the wand. In general, each of the alternative embodiments contain a wand offset portion on which are mounted two or more emitters for emitting positioning signals. As in the preferred embodiment, emitters 48 and 50 are disposed along a pointing axis 46 of the wand. However, in the alternative embodiments, the central axis or pointing direction 46 aligns with a longitudinal axis of the guide means formed integrally with the wand. In each of the alternative embodiments, the guide means is connected to the wand offset portion via an extension.

With reference to FIGURE 2B, a tubular portion 74 is integrated with the wand. The tubular portion defines a bore 76 extending along its longitudinal axis. In intraoperative use, the surgeon probes the patient with the proximal seeking to locate the proper coordinate and trajectory for the surgical tool. Once the coordinate and trajectory are located, the surgeon holds the offset portion while the surgical tool is inserted within the tube. Thereafter, the surgical tool is operated to perform the surgical procedure.

With reference to FIGURE 2C, a second alterative embodiment is shown similar to the previously described alternative embodiment. However, in addition to the structure previously described, a laser 78 is mounted to the offset portion. Light emitting from the laser travels along the longitudinal pointing axis 46 of the bore 76 of the tubular member. In intraoperative use, the surgeon maneuvers the integrated wand and laser while viewing images displayed on the monitor 30. The images selected for display are based upon the coordinate and trajectory of the bore center point at the proximal end of the integrated wand. Once a proper coordinate and trajectory are identified, the integrated wand is held in place while the surgeon activates the laser. Light emitting from the laser intersects the bore center point at the proximal end.

With reference to FIGURE 2D, a third embodiment is shown in which a grooved guide member portion 80 is incorporated into the wand. Th grooved member is connected to the offset portion. The grooved member contains a groove 82 having a longitudinal axis which is in line with pointing axis 46 of the wand. This alternative embodiment finds particular usefulness in conjunction with n edl biopsies. In intraoperative use, a biopsy needle 84 is positioned within the groove so that a tip 86 of the biopsy needle aligns with the groove center point at the proximal end of the integrated wand. The biopsy needle is held in place by a restraining means such as Velcro® straps 88 attached to the sides of the grooved member.

In the embodiment of Figure 2E, the wand 40 has emitters 50, 50', 50" mounted off the axis 46. Because the relationship between the emitter location and the axis 46 is fixed, once the emitters are located, the axis 46 is determined.

In the embodiment of Figure 2F, there are more than two emitters 50_1, 50_2, 50_3, ... Although any two emitters would determine the axis 46, greater accuracy is obtained by redundantly determining the axis 46 and averaging the results. Preferably, a least squares fit is used to compensate for any deviation in the axis 46 determined by the various emitter pairs.

In the embodiment of Figure 2G, the wand 40 has interchangeable tips. The wand 40 includes a first connector portion 90 which selectively connects with a second connector portion 92 of the tips. Various connector systems are contemplated such as a threaded bore and threaded shaft, a snap lock connector means, bayonet connector, spring lock, or other connector systems. A key and keyway system 94 or other means for fixing the alignment of the tips and the wand is particularly advantageous when the connector is off the axis 46.

Various tips are contemplated. A short tip 96 is provided for accurate registration. A longer tip 98 facilitates reaching deeper into interior regions of the subject. Tubular drill guides 100 can be provided in various diameters to accommodate different size drills. An adapter 102 enables endoscopes and other tools to be attached to the wand. Tools and equipment, such as an array of ultrasonic transducers 104, can be connected to the adaptor 102 or configured for direct connection to the wand. A wide variety of other tips for various applications are also contemplated.

The preferred embodiment uses the stereotaxic wand 40 to align the coordinate system of the operating room including the patient, the tool guide, and wand with the coordinate system of a previously prepared three-dimensional image stored in memory. Prior to identifying the proper coordinate and trajectory of the tool guide, the patient space is aligned with or referenced to the stored three-dimensional image data preferably using the following technique.

With reference to Figure 3, when the receivers 14 are microphones, a plurality of reference emitters 106 are mounted on the frame 12. The reference receivers are each spaced along side dges of the frame by known distances from adjacent receivers or microphones 14, e.g. by distances S_1 and S_2. Preferably $S_1=S_2=S$. Each reference receiver is also spaced by a distance D across th frame from an oppositely dis-

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posed emitter.

The distance from the wand emitters to the frame, hence the position of the wand relative to the patient, is determined by the travel time of the sound. The velocity of the sound pulse through air is dependent upon both the temperature, the humidity, and the chemical composition of the air. These factors can and do vary significantly during an operation and from procedure to procedure. As shown in Figure 4, a calculation is performed to determine the speed of sound in the operating room. A calibrating means 110 selectively pulses the reference emitters 106, receives the signals at microphone receivers 14, and processes the elapsed time information in accordance with the procedure of Figure 4. More specifically, the calibration means 110 includes a step or means 112 for causing a first of the reference emitters 106 to emit a signal pulse. A step or means 114 acquires the range values D', i.e. the time required for the ultrasonic pulses to traverse the distance D. A step or means 116 causes this procedure to be repeated a preselected number of times, such as once for each of the four emitters illustrated in FIGURE 3.

Once the travel time between each emitter and receiver pair has been obtained a preselected number of times, a step or means 120 corrects the times for fixed machine delays. That is, there is a fixed, small delay between the time when the command is given to fire the reference emitters 106 and the time that they actually produce a detectable ultrasonic signal. Analogously, there is a small delay between the time that the ultrasonic pulses reach the receiver or microphone 14 and the time that it becomes a measurable electrical signal received by the computer processor. These delays are subtracted from the times measured by step or means 114. An averaging means 122 averages the actual times after correction for the machine delays for transmission of the ultrasonic pulse between the transmitter and receiver. The time over the range values D' provide the most accurate results. A step or means 124 computes a calibration factor F indicative of the current speed of the ultrasound signal adjacent the patient in the operating room. In the preferred embodiment, the calibration factor F is a ratio of the sonicly measured distance D' versus a precise mechanical measurement of the distance D.

With reference to Figures 5A, 5B, and 5C, a wand coordinate and trajectory determining means 130 determines the position of the two emitters 48 and 50, respectively. More specifically, a step or means 132 causes the emitter 48 to emit an ultrasonic signal. The receivers 14 on the frame 12 receive the ultrasonic signal at corresponding times L_1-L_4. A step or means 134 acquires and retains these times. A step or means 136 causes the second emitter 50 to transmit. A step or means 138 acquires the four times L_1-L_4 which are required for the ultrasonic signals to pass from the second emitter to the microphones 14. The speed of ultrasonic transmission and accuracy of transmission times are such that these distances can b measured to within a millimeter or better. A step or means 140 causes the emitters to emit and corresponding data values L_1-L_4 to be acquired each of a plurality of times to improve digitation accuracy, e.g. two times.

When sonic emitters are used, a step or means 142 causes the calibration means 110 to perform the steps described in conjunction with FIGURE 4 in order to provide a current indication of the velocity of sound adjacent to the patient. Of course, the calibration procedure of FIGURE 4 may be performed immediately before steps 132-138 or intermittently during the collection of several data values for averaging. A step or means 144 corrects the values L_1-L_4 for the fixed machine delay discussed above in conjunction with step or means 120. A step or means 146 corrects each of the times L_1-L_4 that were required for the ultrasonic signals to travel from the first and second emitters 48, 50 to the receivers 14 in accordance with the correction factor F determined by step or means 124. An averaging means 148 averages the delay and calibration corrected times L_1-L_4, hence distances between each of the wand emitters 48, 50 and each of the receivers 14. From these distances, provided at least three receivers 14 are provided, a step or means 150 calculates the Cartesian coordinates (x_1,y_1,z_1) and (x_2,y_2,z_2) in the patient space for the two emitters 48 and 50. The first emitter coordinates x_1,y_1,z_1 are calculated from three of the four range values L_1-L_4. With L_4 disregarded, the coordinates are calculated as follows:

$$x_1 = [(L_1^2 - L_2^2) + S^2]/2S \quad (1a),$$

$$y_1 = [(L_1^2 - L_3^2) + S^2]/2S \quad (1b),$$

$$z_1 = [L_1^2 - x_1^2 - y_1^2]^{1/2} \quad (1c),$$

where $S=S_1=S_2$ as defined in FIGURE 3. Preferably, the three selected range values are the three shortest of L_1-L_4. Similar computations are calculated for x_2, y_2, and z_2 coordinates of the second emitter. A step or means 152 checks the validity of the measurement. More specifically, the known separation between the wand emitters is compared with the separation between the measured coordinates x_1,y_1,z_1 and x_2,y_2,z_2 of the wand emitters, i.e:

$$|Sep_{known} - [(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2]^{1/2}| \leqq \text{error.} \quad (2).$$

If the measured and known separation is greater than the acceptable error, e.g. 0.75 mm when measuring with a resolution of 1 mm, an erroneous measurement signal is given. The measurement is discarded and the surgeon or other user is flagged to perform the measurement process 130 again. A step or means 154 from the coordinates of the two emitters 48, 50, and from th g ometry of the wand discussed in Figure 2, calculates the Cartesian coordinates (x_0,y_0,z_0) for the wand tip 44.

The tip coordinates x_0, y_0, z_0 are defined by:

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$$r = \ell_1/\ell_2 \quad (3a),$$
$$x_0 = (1 + r)x_1 - rx_2 \quad (3b),$$
$$y_0 = (1 + r)y_1 - ry_2 \quad (3c),$$
$$z_0 = (1 + r)z_1 - rz_2 \quad (3d).$$

Before the wand and tool guide can be used to locate a proper coordinate and trajectory for a surgical tool such as a drill, the patient space (x,y,z) is aligned with the image space (x',y',z') stored in memory. Aligning the spaces begins with referencing known positions or points 164 in the patient space with the wand tip. For example, the tip 44 of the wand may be referenced to three independent positions of the vertebra, i.e. the tips of the spinous and traverse processes. These positions 164 on the vertebra are compared with the relative position of pixels 162 in the image space. Thereafter, with reference to FIGURE 6, a transform means 160, as shown in FIGURE 6, transforms the coordinates of the patient space into the coordinate system of the image space. Fiducials can also be used by the transform means 160 to transform or match the coordinates of other patient space points 164 into the coordinate system of the image space. To this end, three or more fiducials or markers are affixed at three or more spaced points on the patient's body. The fiducials are visible in the imaging medium selected such that they show up as readily identifiable dots 162 in the resultant image data. The fiducials are markers or small beads that are injected with radiation opaque and magnetic resonance excitable materials. A small dot or tattoo is made on the patient's skin and a fiducial is glued to each dot. This enables the position 164 of the fiducials to be denoted even if the fiducials are removed in the interval between the collection of the image data and the surgical procedure. To align the images of the fiducials with the fiducial positions in patient space, the tip of the wand is placed on each fiducial or tattooed marker point 164. The coordinates in patient space of each vertebra process tip or fiducial are determined with the procedure described in conjunction with FIGURES 5A-5C.

The position of the three fiducials or process tips are compared with the relative position of the pixels 162 in the image space. The patient space coordinates of marks 164 or the process tips of the patient in the coordinate system of the patient support are measured. A like coordinate system through the pixels 162 is defined and compared to the patient space coordinate system. The translation and rotational relationship between image space and patient space coordinate systems is determined. With reference to FIGURE 6A, the position of the patient in operating room space (x,y,z) and the relative position in image space (x',y',z') are determined. That is, two coordinate systems are defined. The translation means first determines the offset x_{offset}, y_{offset}, z_{offset} betw en the barycenters 166, 168 of the triangles defined by the coordinates of three fiducials or process tips in data and patient space, respectiv ly. This provides a translation or an offset in the x, y, and z-directions between the two coordinate systems. The values of x_{offset}, y_{offset}, and z_{offset} are added or subtracted to the coordinates of the patient space and the coordinates of image space, respectively, to translate between the two.

With reference to Figure 6B, translating the origins of the two coordinate systems into alignment, however, is not the complete correction. Rather, the coordinate systems are normally also rotated relative to each other about all three axes whose origin is at the barycenter. As illustrated in Figures 6B, 6C, and 6D, the angle of rotation in the (y,z), (x,z), and (x,y) planes are determined. Having made these determinations, it is a simple matter to transform the patient support space coordinates into the image space coordinates and, conversely, to rotate the image space coordinates into patient space coordinates. The wand coordinate means 130 is connected through the transform means 160 with one of the plane selecting means 24 and the video processor 28 to cause a marker, e.g. cross hairs, to be displayed on the monitors 30 at the coordinates of the wand tip. This enables the surgeon to coordinate specific points on the patient or in the incision with the images.

Having aligned the image and patient spaces the wand and tool guide can be used to identify the entry coordinate and trajectory at which the surgical tool will be applied to the patient. For example, the surgeon may use the wand and tool guide in combination to identify the trajectory and coordinate on the spinal column at which the surgeon will utilize a surgical drill in order to drill a hole for the placement of a spinal screw. Holding the wand and drill guide in one hand, the surgeon moves the combination around the exposed vertebra while viewing images displayed on a monitor selected in accordance with the wand tip. The image provide a cross-sectional view of the vertebra and allow the surgeon to plan with greater accuracy the angle and depth at which the drill will be operated. Once the coordinate and trajectory of the drill application is identified, the surgeon may remove the wand while holding the tool guide in place. Since the tool guide comes with a handle, the surgeon can hold the tool guide in place even when the spinal column moves in response to patient breathing. In other words, the surgeon can easily hold the bore of the tool guide at the trajectory identified even while the spinal column experiences movement. With the guide properly oriented, the surgeon inserts into the bore the surgical tool and tip needed for the spinal screw fixation. This technique is superior over prior methods in which surgeons relied solely on their own skill and knowledge of the patient's unique anatomy and will result in far few r sub-optimal results.

The present invention is also useful in preplanning a surgical op ration. For example, surgeons may use images of the body portion at which the surgical

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tool will be inserted in order to determine prior to the operation, the best trajectory and coordinate at which the tool should be applied. Once the proper trajection and coordinate are identified, the computer system can store these images in memory to be later used as a reference target to be compared with images produced in connection with the wand and drill guide. In particular, the images produced in accordance with the wand and drill guide could be compared with the stored images until the computer identifies an image match. Once the computer identifies a match, the computer can output a signal to alert the surgeon that the tool guide has been properly oriented.

Claims

1. An apparatus for orienting and guiding the application of a tool into a subject including: a subject support (10) to which a preselected portion of a subject may be secured and which is selectively positionable in a diagnostic imaging system which includes an image memory (22) for storing reconstructed image representations; a display (30) for displaying selected portions of the image representations stored in the image memory in an image coordinate system (x',y',z'); a pointer (44) which is selectively touchable to selected portions of the subject or subject support (10); an electronic position indicator (48, 50) for providing an electronic indication of points (164) of the subject or subject support portions touched by the pointer in a subject coordinate system (x,y,z); and means (160) for correlating the subject coordinate system (x, y, z) with the image coordinate system (x', y', z') the apparatus being characterised by: a guide (60) for defining a path extending longitudinally along a guide axis (46), the guide (60) being configured for selectively receiving a tool (84) along the guide axis (46); and means (48, 50) connected with the guide (60) for providing electronic signals to the correlating means (160) for coordinating a coordinate system of the guide (60) with the image coordinate system (x', y', z').

2. An apparatus as set forth in Claim 1 wherein the guide (60) is configured for selectively receiving the pointer (44) and has means (90, 92, 94) for locking the pointer (44) in a preselected position relative to the guide axis (46).

3. An apparatus as set forth in Claim 1 wherein the guide (60) has at least a pair of emitters (48, 50) for selectively emitting signals which are transmitted through the air; and the apparatus further includes receivers (14) for receiving the signals from the emitters (48, 50); and a ranging means (110) for determining the position of the emitters (48, 50) in the subject coordinate system.

4. An apparatus as set forth in Claim 3 wherein the guide (60) includes a groove or bore (76, 82, 100) for receiving the tool (84) and wherein the emitters (48, 50) are mounted in a preselected location relative to the groove or bore (76, 82, 100) such that the ranging means (110) determines a trajectory along the groove or bore (76, 82, 100).

5. An apparatus as set forth in Claim 2 further including a plurality of guide tips (96, 98, 100, 102, 104) and means (90, 92, 94) for selectively connecting the tips to the guide (60), at least one of the tips (96) being configured such that a pointing axis of the tip is in alignment with the guide axis (46).

6. An apparatus as set forth in any of the preceding claims further including a laser (78) mounted for outputting light along the path defined by the guide axis (46).

7. An apparatus as set forth in any of the preceding claims wherein the guide (60) includes: a guide portion (74, 80) for receiving the tool (84) along the guide axis (46); a handle (62) for holding the guide portion; and means (48, 50) for signaling the guide axis.

8. An apparatus as set forth in any of the preceding claims wherein the guide (60) includes an interconnection means (64, 70) for selective interconnection with a wand (40) that carries the pointer (44) and emitters (48, 50) for signaling a location of the pointer in the subject coordinate system.

9. A method of orienting a tool (84) and guiding an application of the tool (84) into a subject in which a pointer (44) and guide (60) in combination are manoeuvered to a proposed entry point and a trajectory (46) for application of the tool (84) is defined; the method including electronically signaling the trajectory and entry point; correlating (160) a coordinate system of the subject and the signaled entry point and trajectory with a coordinate system of an electronic image representation stored in an image memory; and generating a human-readable display (30) of at least a portion of the image representation with the trajectory and entry point superimposed thereon, the method being charact rised by: defining with the guide (60, 80) a tool receiving guide path (66, 76, 82) disposed in alignment with the trajectory; and inserting the tool (84) along the guide path (66, 76, 82) and into the subject along the trajectory through the proposed entry point.

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10. A method as set forth in Claim 9 including inserting into the guide (60, 80) a wand (40) which carries a pair of emitters (48, 50) for signaling the trajectory and a location of its tip (44) in the guide (60); positioning the guide (60) such that the tip (44) of the wand touches the proposed entry point; and, after correlating the entry point and the trajectory with the electronic image representation, removing at least a pointer portion of the wand from the guide (60) prior to inserting the tool (84) into the guide (60).

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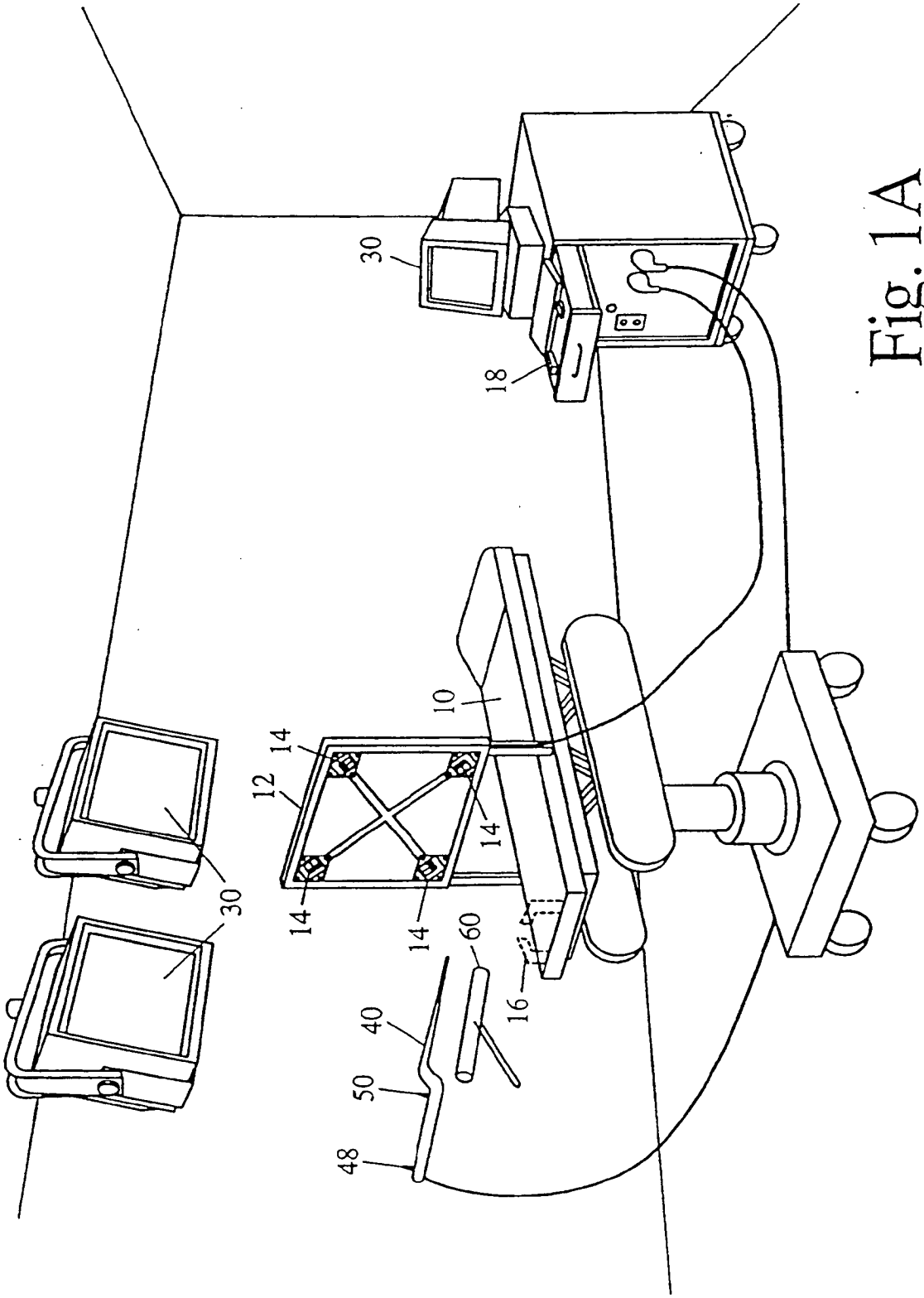

Fig. 1A

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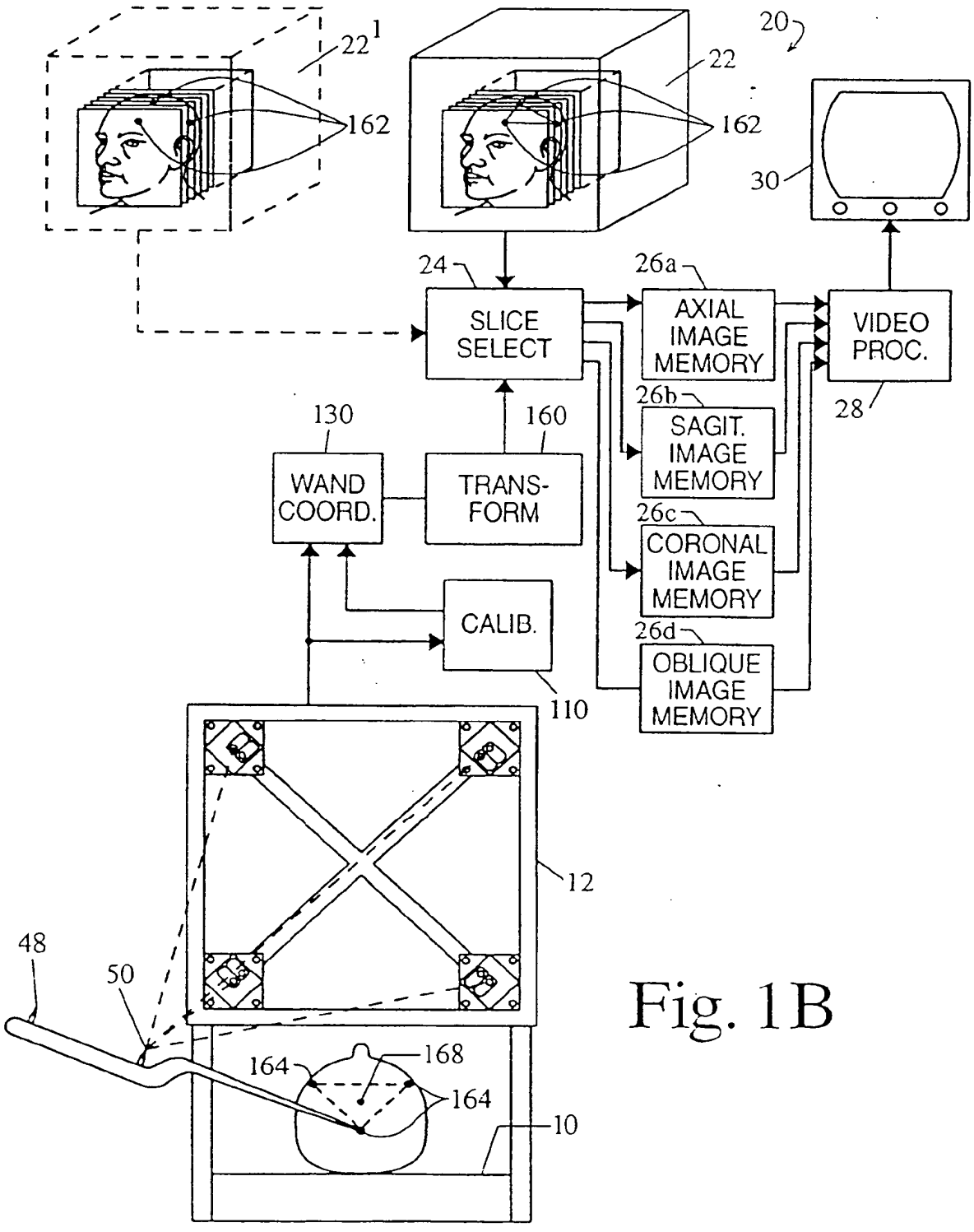

Fig. 1B

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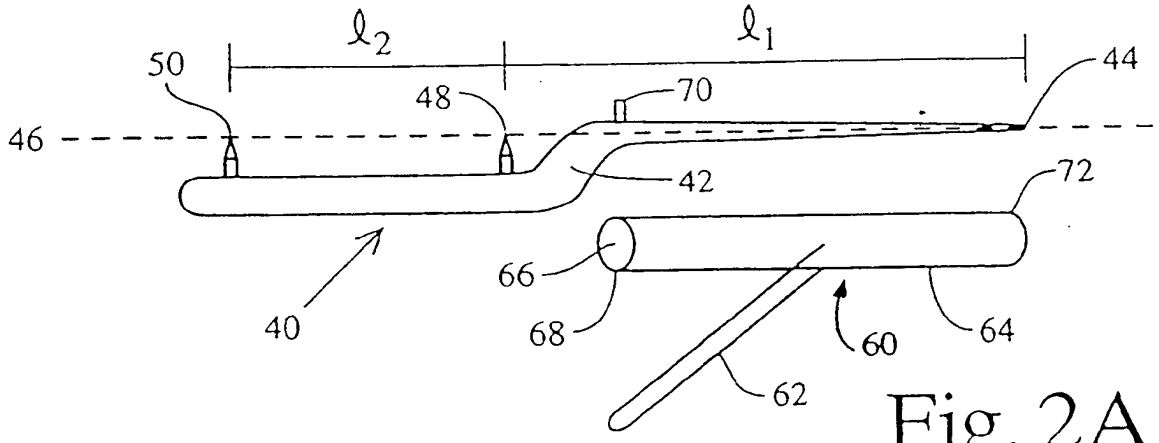

Fig. 2A

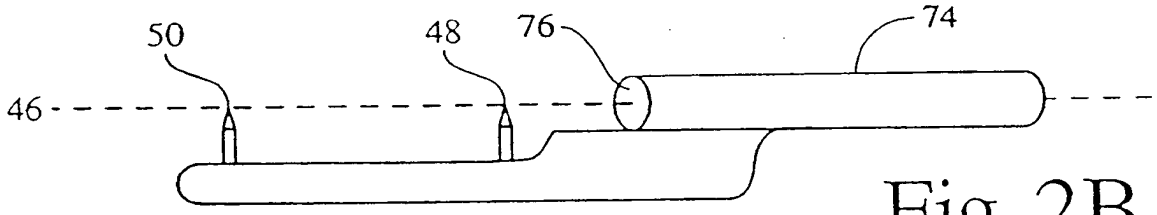

Fig. 2B

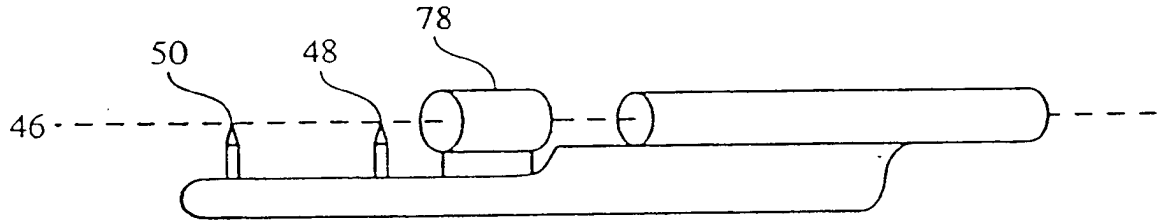

Fig. 2C

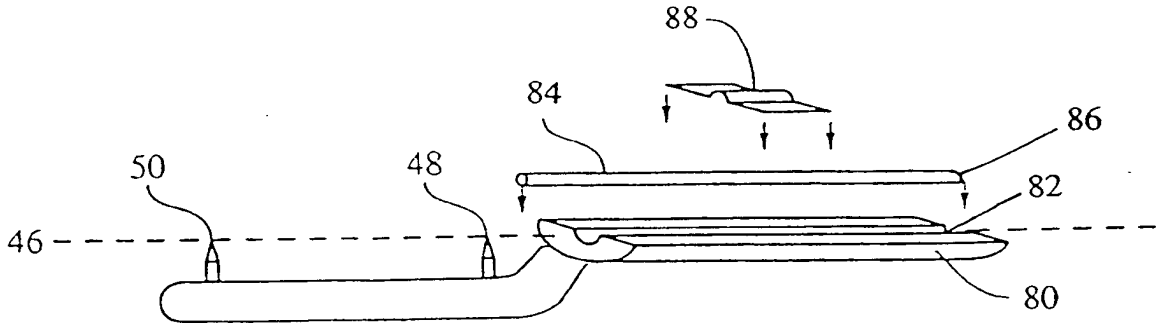

Fig. 2D

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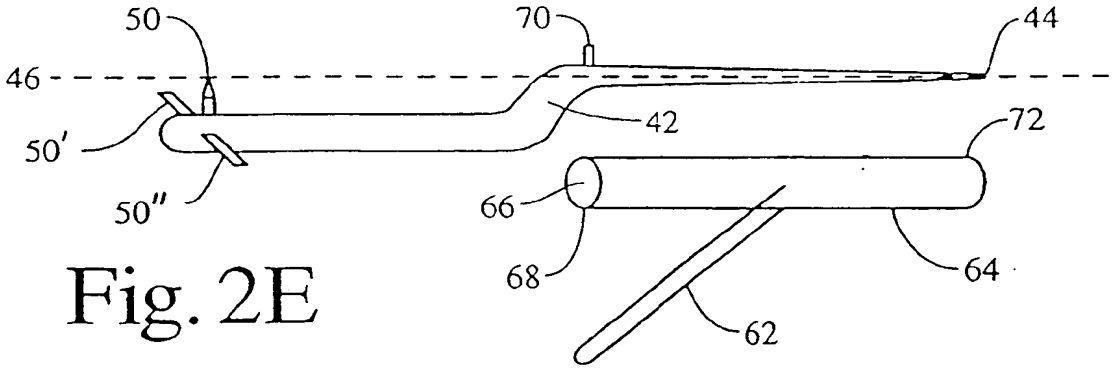

Fig. 2E

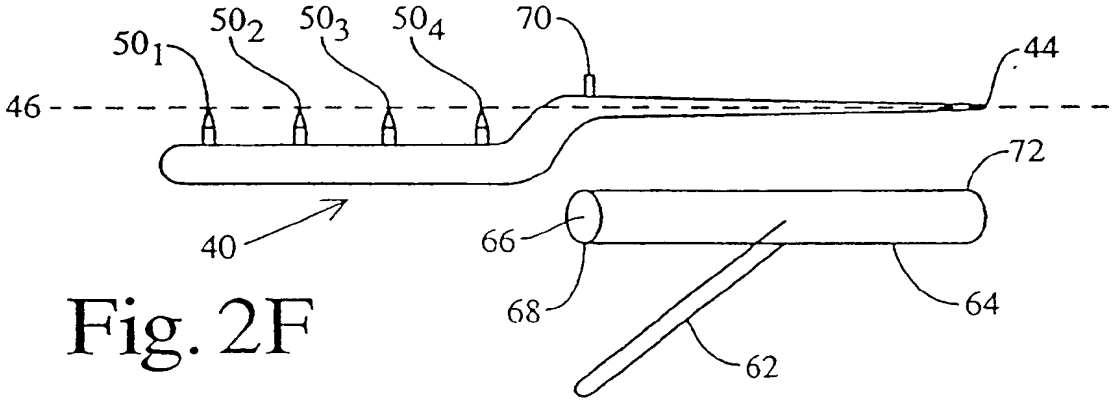

Fig. 2F

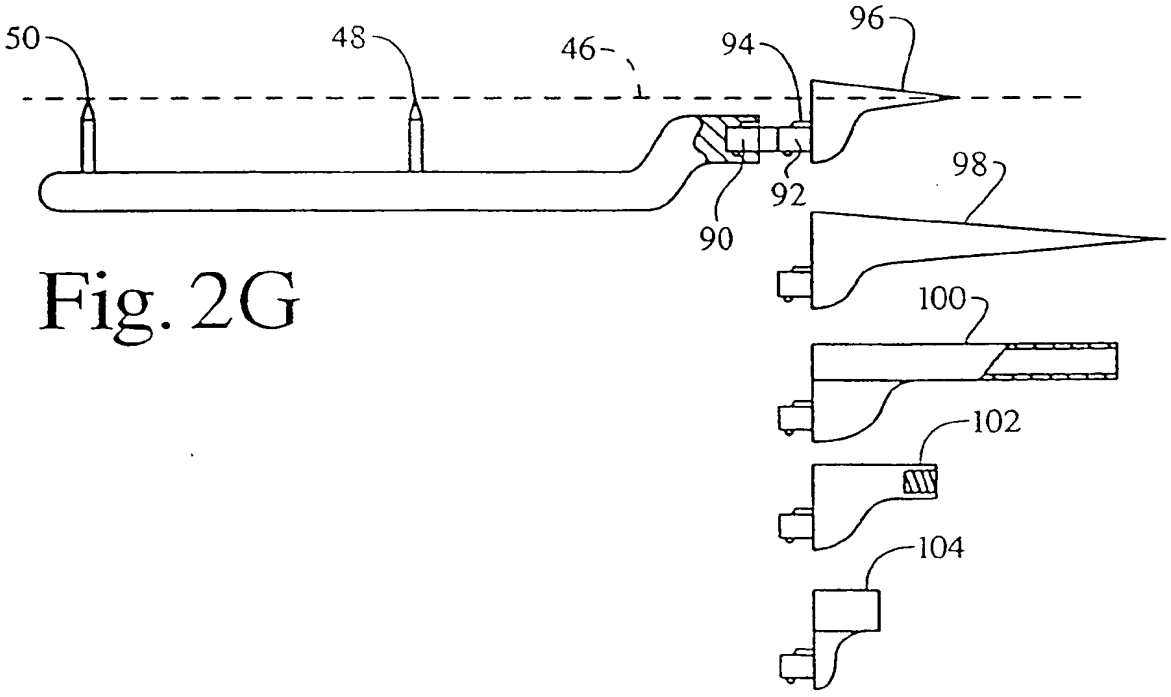

Fig. 2G

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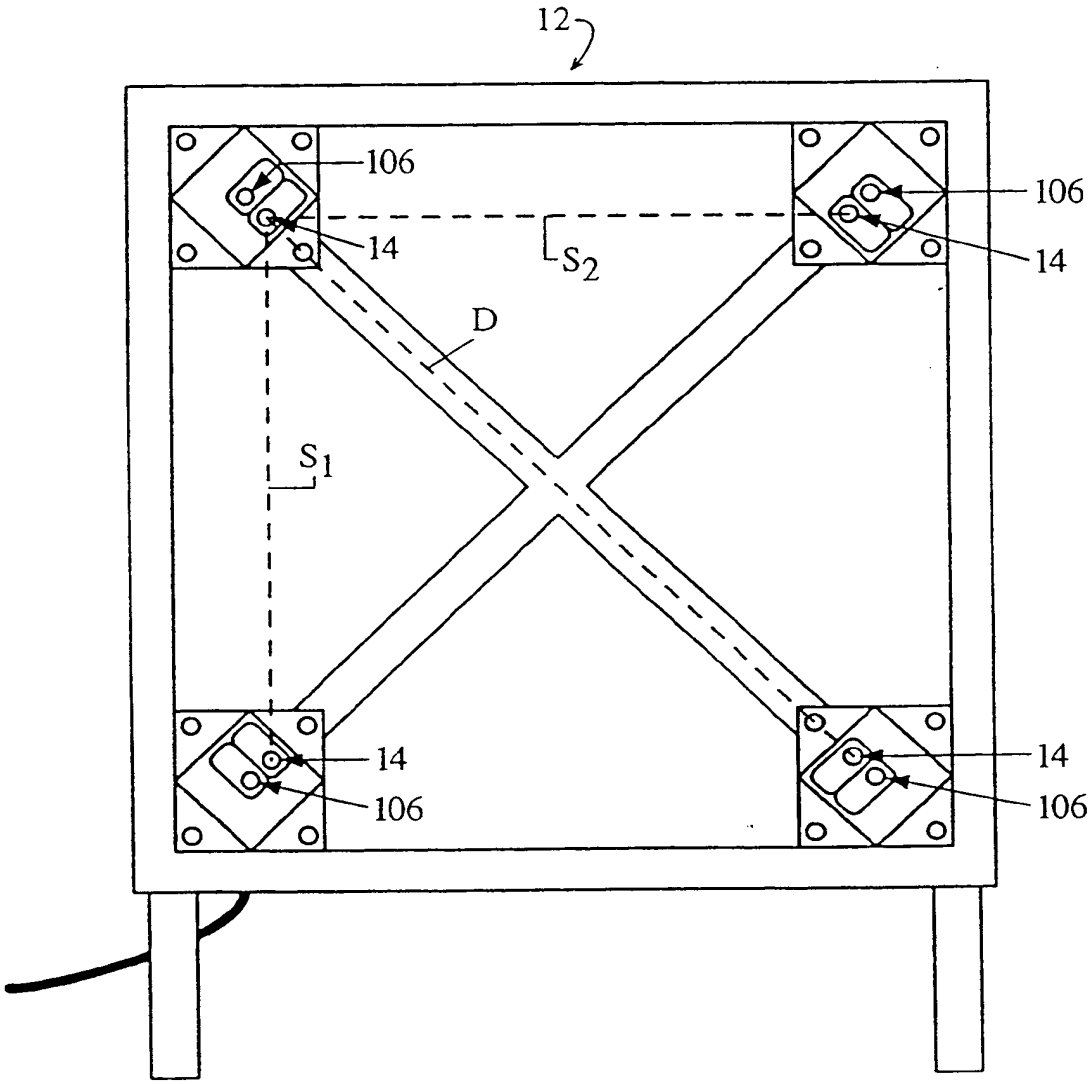

Fig. 3

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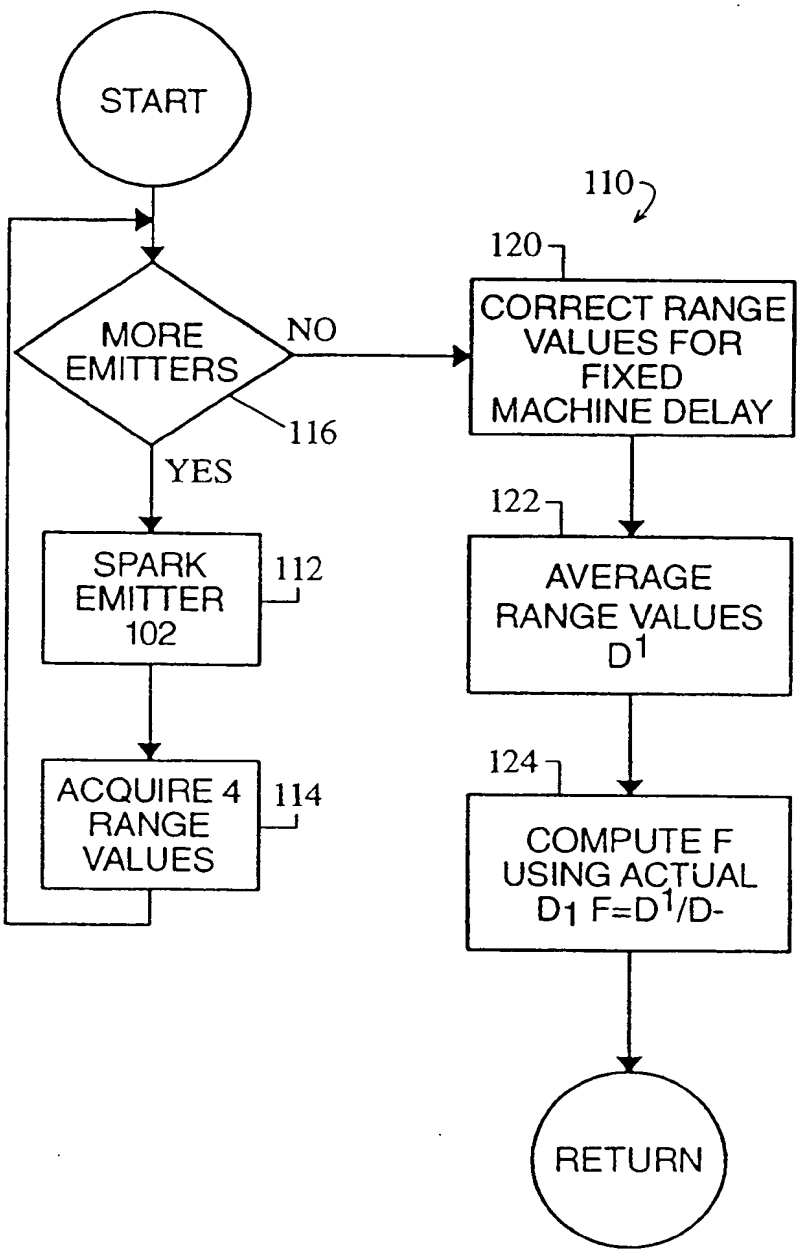

Fig. 4

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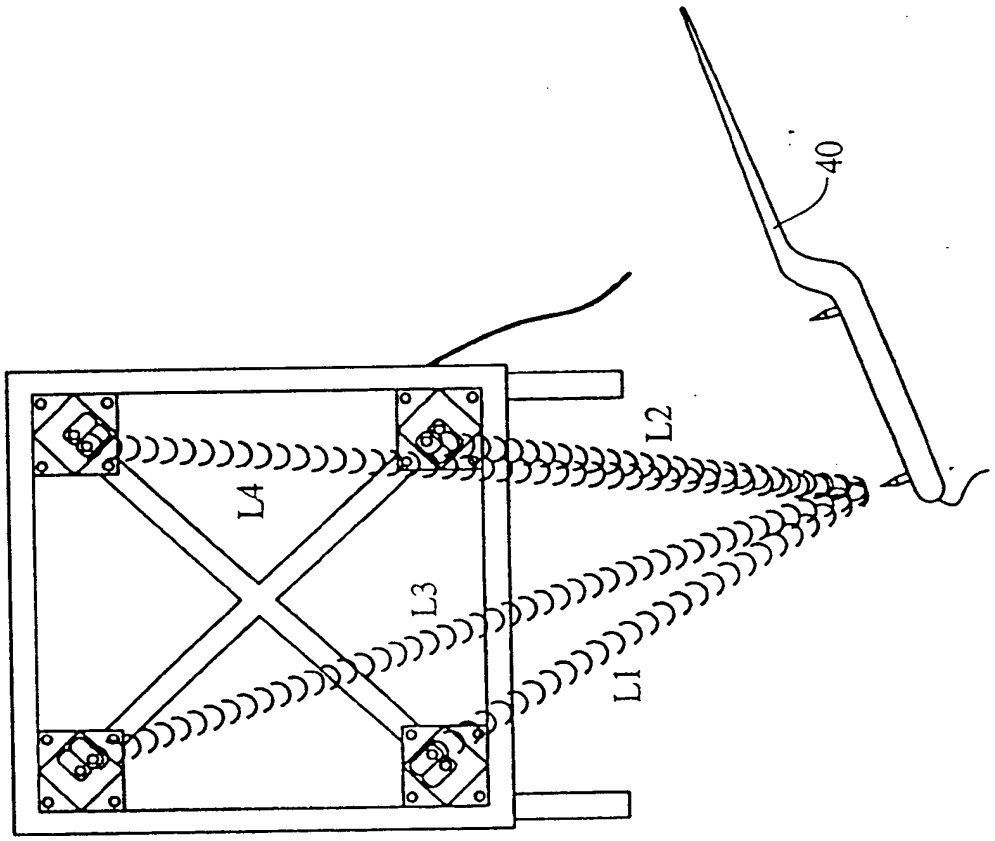

Fig. 5B

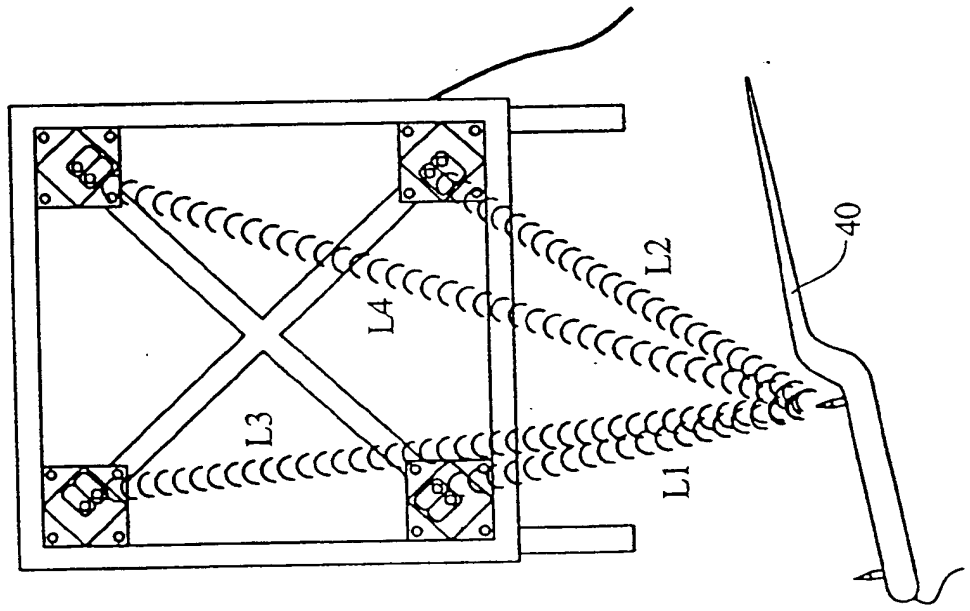

Fig. 5A

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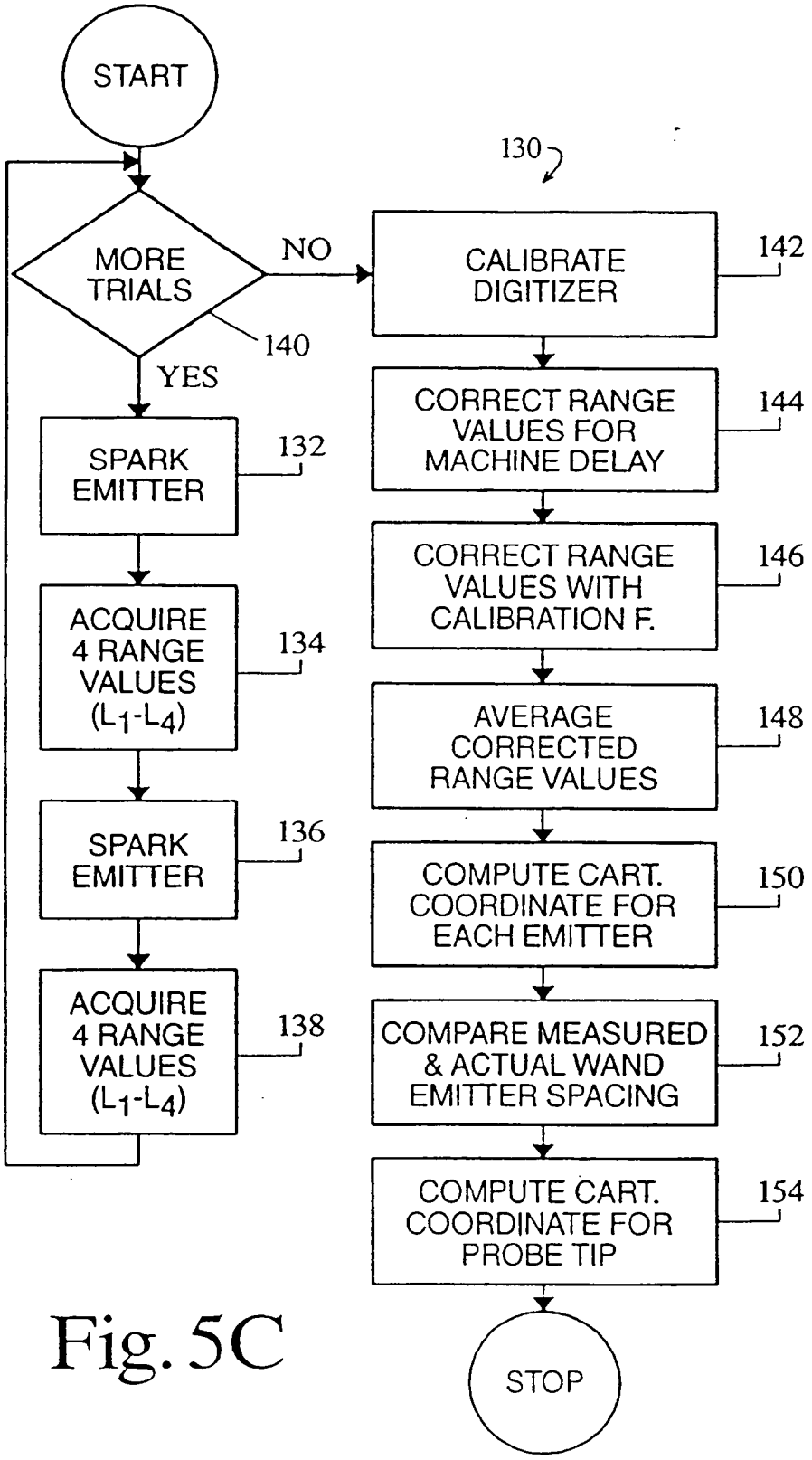

Fig. 5C

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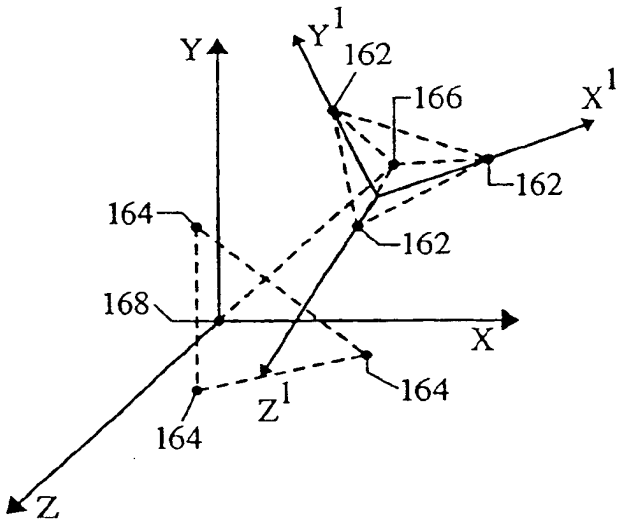

Fig. 6A

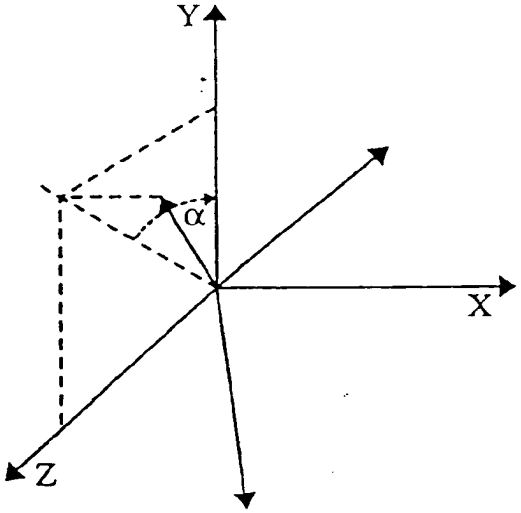

Fig. 6B

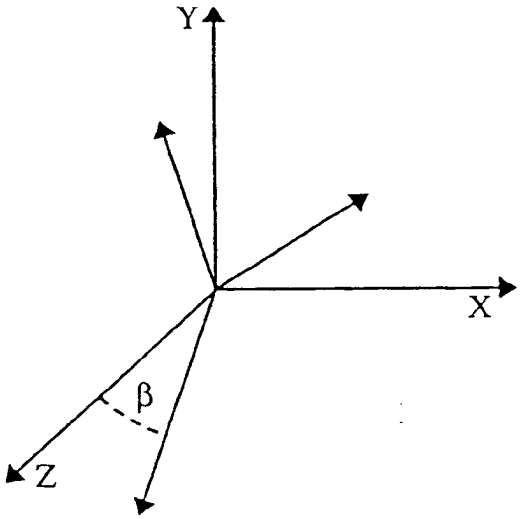

Fig. 6C

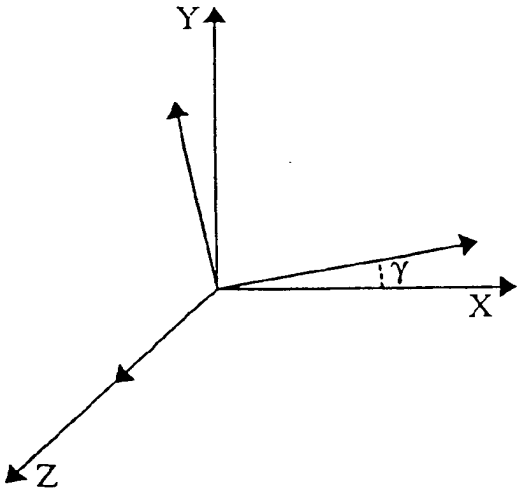

Fig. 6D

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European Patent Office

PARTIAL EUROPEAN SEARCH REPORT

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number EP 95 30 1778

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	WO-A-91 04711 (DIADIX) * figures 1,4 *	1-8	A61B19/00 A61B17/34
Y	EP-A-0 427 358 (ALLEN) * column 3 - column 5 *	1-5,7,8	
Y	EP-A-0 456 103 (IBM) * column 4, last paragraph *	1-5,7,8	
A	EP-A-0 469 966 (FARO) * page 6, line 49 - page 7, line 3 * * page 9, line 40 - line 41 *	1,2,5	
A	US-A-5 279 309 (TAYLOR) * abstract *	3,8	
A	WO-A-94 06352 (FISCHER) * page 16, paragraph 3 *	1	
A	WO-A-93 10710 (FISCHER) * abstract *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US-A-5 078 142 (SICZEC) * abstract *	1	A61B

INCOMPLETE SEARCH

The Search Division considers that the present European patent application does not comply with the provisions of the European Patent Convention to such an extent that it is not possible to carry out a meaningful search into the state of the art on the basis of some of the claims

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

Place of search	Date of completion of the search	Examiner
THE HAGUE	31 July 1995	Barton, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C07)

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-C-

INCOMPLETE SEARCH

Claims not searched: 9,10

Method for treatment of the human or animal body by surgery or therapy (see article 52(4) of the European Patent Convention)

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